



Elmer/Ice Beginner course 2023

CSC, Espoo, Finland

Introduction

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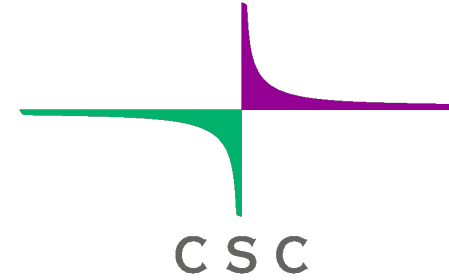
Samuel COOK ⁽²⁾

Olivier GAGLIARDINI ⁽³⁾

- (1) CSC - IT Center for Science Ltd. – Espoo – Finland
- (2) University of Lausanne – Switzerland
- (3) University Grenoble Alpes / CNRS - IGE - Grenoble – France

Thanks to ...

- **CSC-IT Center for Science** for hosting the course
- **IGE, UGA** and **SNO-Elmer/Ice** at **CNRS** for supporting Olivier Gagliardini's travel and stay
- **UNIL** for supporting Samuel Cook's travel and stay
- **You** for being here



Program

Day 1, Nov. 13rd - Introduction + Synthetic Glacier

- **09:00** – 10:30 Welcome and introduction to Elmer/Ice + SIF crash course
- 10:30 – 11:00 Break
- 11:00 – 12:30 Synth Glacier Step 1
- 12:30 – 13:30 Lunch
- 13:30 – 14:30 Synth Glacier Step 2
- 14:30 – 15:00 Break
- 15:00 – **16:00** Synth Glacier Step 3

Day 2, Nov. 14th – Case Argentière

- **09:00** – 10:30 Diagnostic runs
- 10:30 – 11:00 Break
- 11:00 – 12:00 Ice age
- 12:00 – 13:00 Lunch
- 13:00 – 14:30 SMB and Prognostic
- 14:30 – 15:00 Break
- 15:00 – **16:00** Discussion and wrap-up



- **Elmer** (= multi-physics package) with additional routines for Glaciology
- Maintained and supported by **CSC**
- **Open Source** (GPL2 or later)
 - Transparency (you co-own the code)
 - Sustainability (no license fees)
 - Viral effect of GPL (new code also GPL)
 - Linking to library allowed under LGPL
- Large international user community
 - Knowhow of well-established institutions
- Good level of support/documentation
<http://elmerice.elmerfem.org>

- Elmer/Ice builds on Elmer and includes developments related to glaciological problems. Elmer/Ice includes a variety of dedicated solvers and user functions for glaciological applications and their development is supported by various groups and funding...



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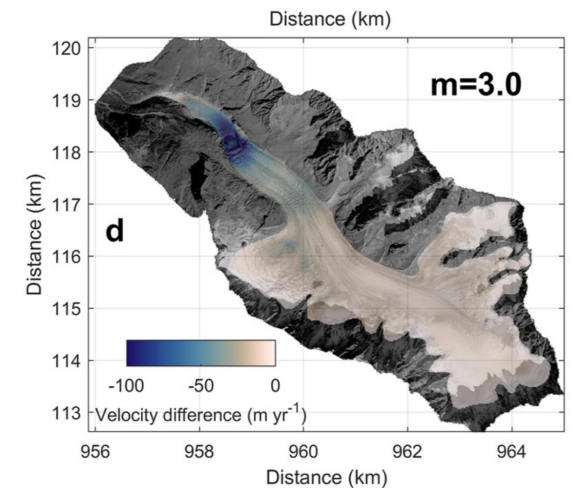
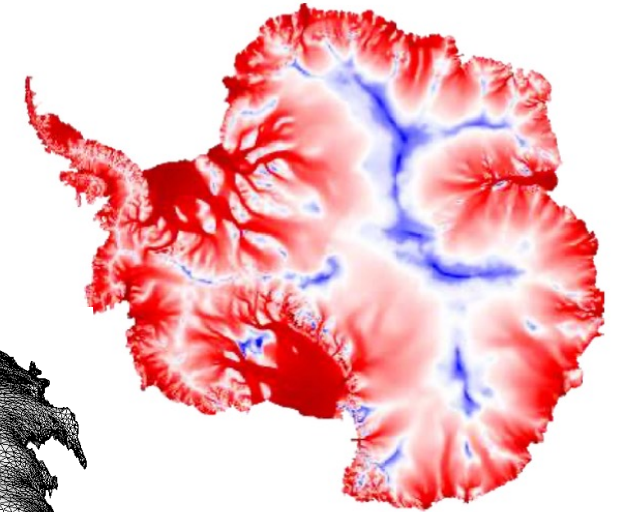
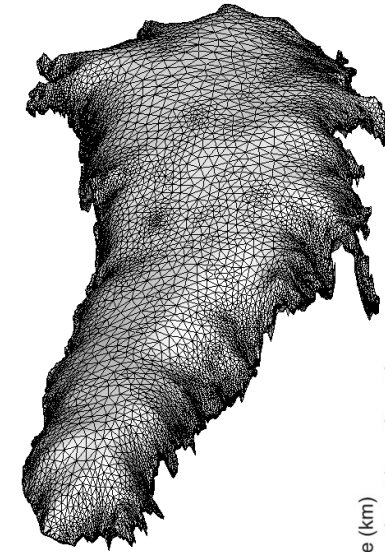
Tipping Points in Antarctic
Climate Components



Elmer/Ice



- **Full-Stokes** (also SIA, SSA, Blatter-Pattyn) with post processing for stress/strain
- **Mesh**: Unstructured, vertically extruded, deforming and moving meshes
- **Temperature** solver accounting for pressure melting point or Enthalpy solver
- **Rheology**: Glen, anisotropy, firn densification, damage mechanics
- Special **sliding laws**: Weertman, Coulomb, Budd, Tsai
- Basal **hydrology** models (2): GlaDS and double continuum
- **NetCDF**-readers (for geometry as well as coupling to climate)
- Simple SMB (**PDD**)
- **Calving** models (3 approaches)
- **Inverse methods** for data assimilation
- Methods for **tracer transport/dating**
- Antarctica and Greenland configurations
- ...





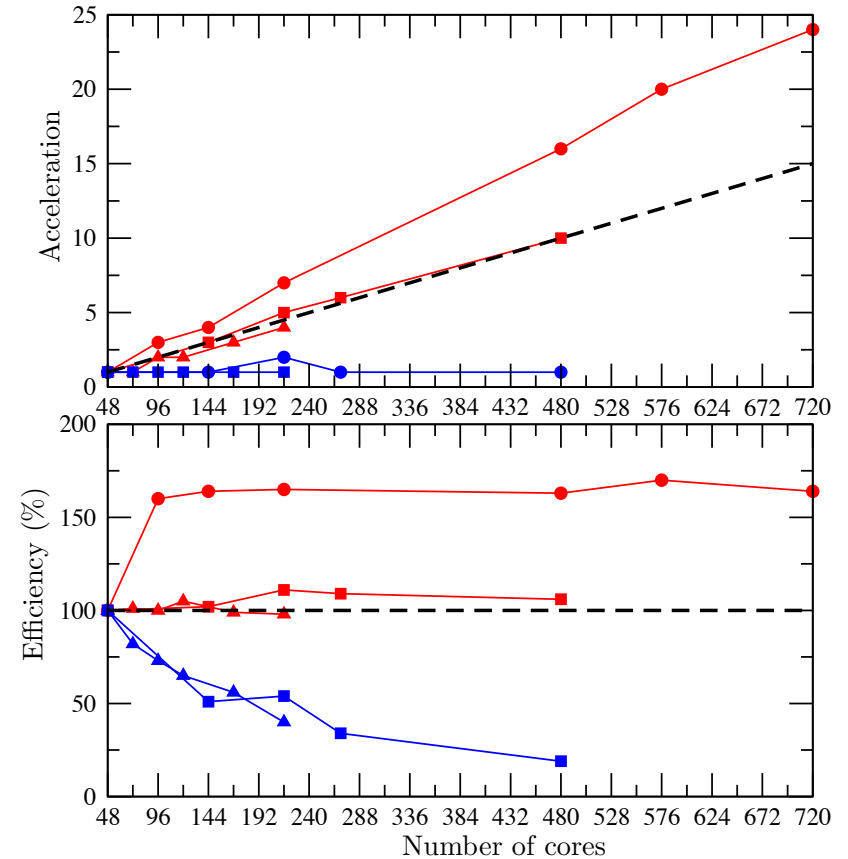
	Flow equations	Stokes	Blatter-Pattyn	SSA	SSA*	SIA	ISCAL
Rheology	Glen	X, Inv Adj + Rob	X	X, Inv Adj	X	X	X
	GOLF	X					
	CAFFE	X					
	POROUS	X					
	Damage	X	X	X	X	X	X
Basal friction	Linear	X, Inv Adj + Rob	X	X, Inv Adj	X		
	Weertman	X	X	X	X		
	Coulomb	X	X	X	X		
	Budd	X	X	X	X		
	Tsai		X	X	X		
Free surface	dS/dt	X	X	X	X	X	X
	dH/dt	X, Inv	X	X, Inv	X, Inv	X, Inv	X, Inv
Grounding line	Contact	X					
	Hydrostatic	X	X	X	X	X	
Calving	Fracture+Damage	2D					
	crevasse depth	X					
Temperature	Temperate	X	X	X	X	X	X
	Enthalpy	X	X	X	X	X	X
Hydrology	Two layers	X	X	X	X		
	GlaDS	X	X	X	X		
Inv : Inverse methods, Adj (adjoint), Rob (Arthen & Gudmundsson, 2010)							



Elmer/Ice



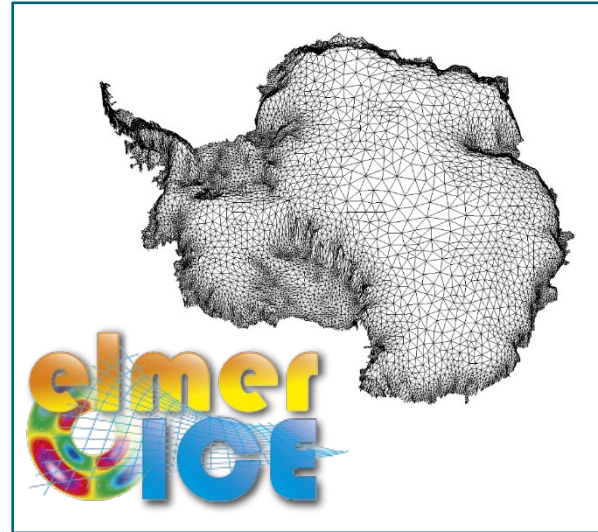
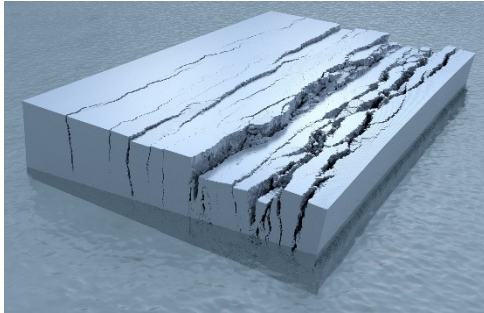
- Finite element method (FEM)
 - Using linear elements and standard Galerkin with Stabilized Finite Elements or residual free bubbles
- Flow law → viscosity changes by order of magnitudes → bad conditioned system:
 - Direct parallel or tuned block-preconditioned iterative Solver
- (Large scale) parallel computing
 - MPI
 - OpenMP multi-threading and vectorization (SIMD)
 - Currently working towards GPUs (AMGX)



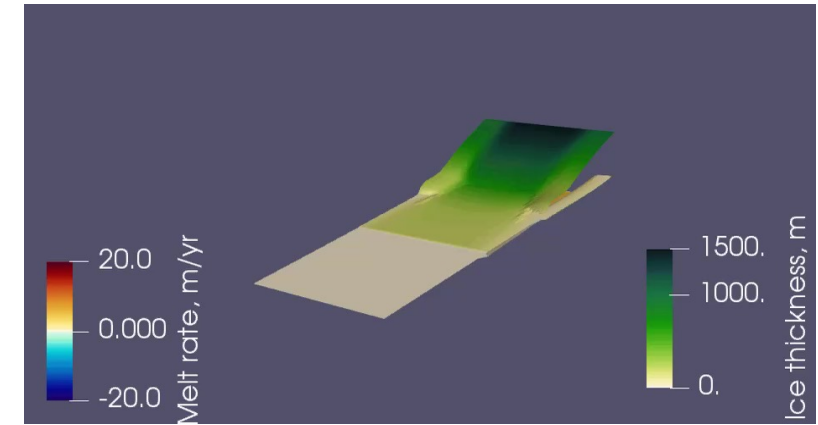
Gagliardini, O., T. Zwinger, F. Gillet-Chaulet, G. Durand, L. Favier, B. de Fleurian, R. Greve, M. Malinen, C. Martín, P. Råback, J. Ruokolainen, M. Sacchetti, M. Schäfer, H. Seddik, and J. Thies, 2013. *Capabilities and performance of Elmer/Ice, a new-generation ice sheet model*, Geosci. Model Dev., 6, 1299-1318, doi:[10.5194/gmd-6-1299-2013](https://doi.org/10.5194/gmd-6-1299-2013).

Elmer/Ice – coupling to other (Elmer) components

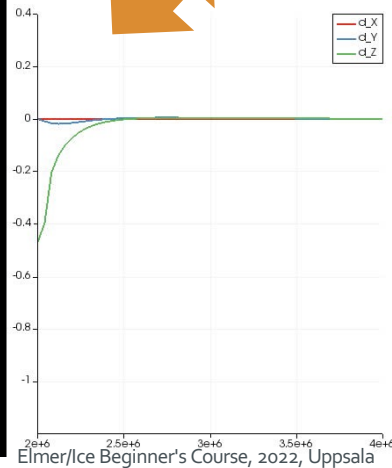
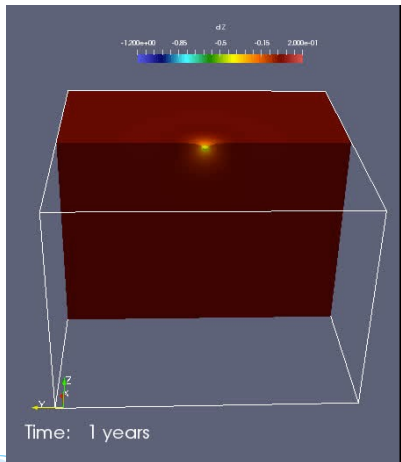
Calving - DEM (HiDEM)



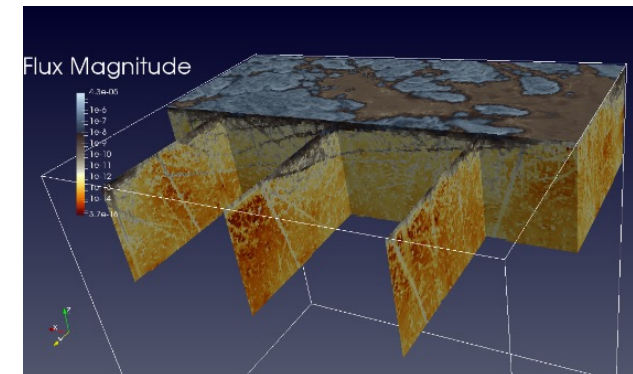
Ice-ocean coupler (FISOC)



Glacial isostasy – VE model



Groundwater and Permafrost model



Elmer/Ice Beginner Course 2023

Elmer/Ice – short history & community activity (1/4)

- ✓ EGU2002: OG was looking for a 3D FE code to model the flow of strain-induced anisotropic polar ice – meet TZ
- ✓ March 2003: OG visited CSC for few days: AIFlowSolver and FabricSolver partly implemented
- ✓ August 2005 – One year visit of OG at CSC (Anisotropy, cavity, glaciers, ISMIP tests, ...)
- ✓ **February 2008 – First Elmer/Ice Course – Grenoble**
- ✓ Elmer/Ice course at Beijing Normal University in March 2011
- ✓ June 2011 – SVALI summer school – Finland
- ✓ **2012 – Elmer/Ice has now a website, a logo and a mailing list**
- ✓ **2012 – Elmer/Ice comes as a Elmer Package – New wiki**
- ✓ 2012 – Elmer/Ice course at UBC/SFU
- ✓ 2013 – Elmer/Ice courses at Univ. Washington and Univ. Alberta
- ✓ **9 April 2013 – First Elmer/Ice users meeting – EGU 2013**

Elmer/Ice – short history & community activity (2/4)

- ✓ May 2013 – Second SVALI summer school – Finland
- ✓ 2-day beginner Elmer/Ice course, 3-4 Oct. 2013, LGGE, Grenoble, France
- ✓ 3-day Elmer/Ice advanced workshop, 4-6 Nov. 2013, CSC, Espoo, Finland
- ✓ April 2014 – Second Elmer/Ice users meeting – EGU 2014
- ✓ 3-day beginner Elmer/Ice course, 27-29 Oct. 2014, IMO, Reykjavík, Iceland
- ✓ April 2015 – Third Elmer/Ice users meeting – EGU 2015
- ✓ 2-day beginner course, 1&2 Nov 2015, CIC, Copenhagen, Denmark
- ✓ 3-day Elmer/Ice advanced workshop, 30 Nov, 1&2 Dec 2015, LGGE, Grenoble, France
- ✓ 3-days beginner course, Oct 2016, Oslo
- ✓ April 2017 – Fourth Elmer/Ice users meeting – EGU 2017
- ✓ 2-day beginner Elmer/Ice course, 23rd and 24th Oct. 2017, University of Stockholm, Sweden

Elmer/Ice – short history & community activity (3/4)

- ✓ 3-day advanced Elmer/Ice workshop, 22nd, 23rd and 24th Nov. 2017, IGE, Grenoble, France
- ✓ 2-day beginner Elmer/Ice course, 22nd & 23rd Oct. 2018, University of Lapland, Rovaniemi, Finland
- ✓ 3-day Elmer/Ice advanced users workshop, 29th-31st Oct. 2018, CSC, Espoo, Finland
- ✓ April 2019 - Fifth Elmer/Ice Users Meeting - EGU 2019
- ✓ 2-day beginner Elmer/Ice course, 28&29 October 2019, University of Iceland, Iceland
- ✓ Sixth Elmer/Ice Users Meeting - Remotely May 2020
- ✓ Seventh Elmer/Ice Users Meeting - Remotely October 2020
- ✓ **Beginner Elmer/Ice Online course - 23-27 November 2020**
- ✓ 2-day beginner Elmer/Ice course, 8&9 October 2021, Univ. Oslo, Norway
- ✓ Eight Elmer/Ice User Meeting - Remotely February 2022
- ✓ **Creation of the Elmer/Ice Developer's Committee (DevComm) in June 2022**

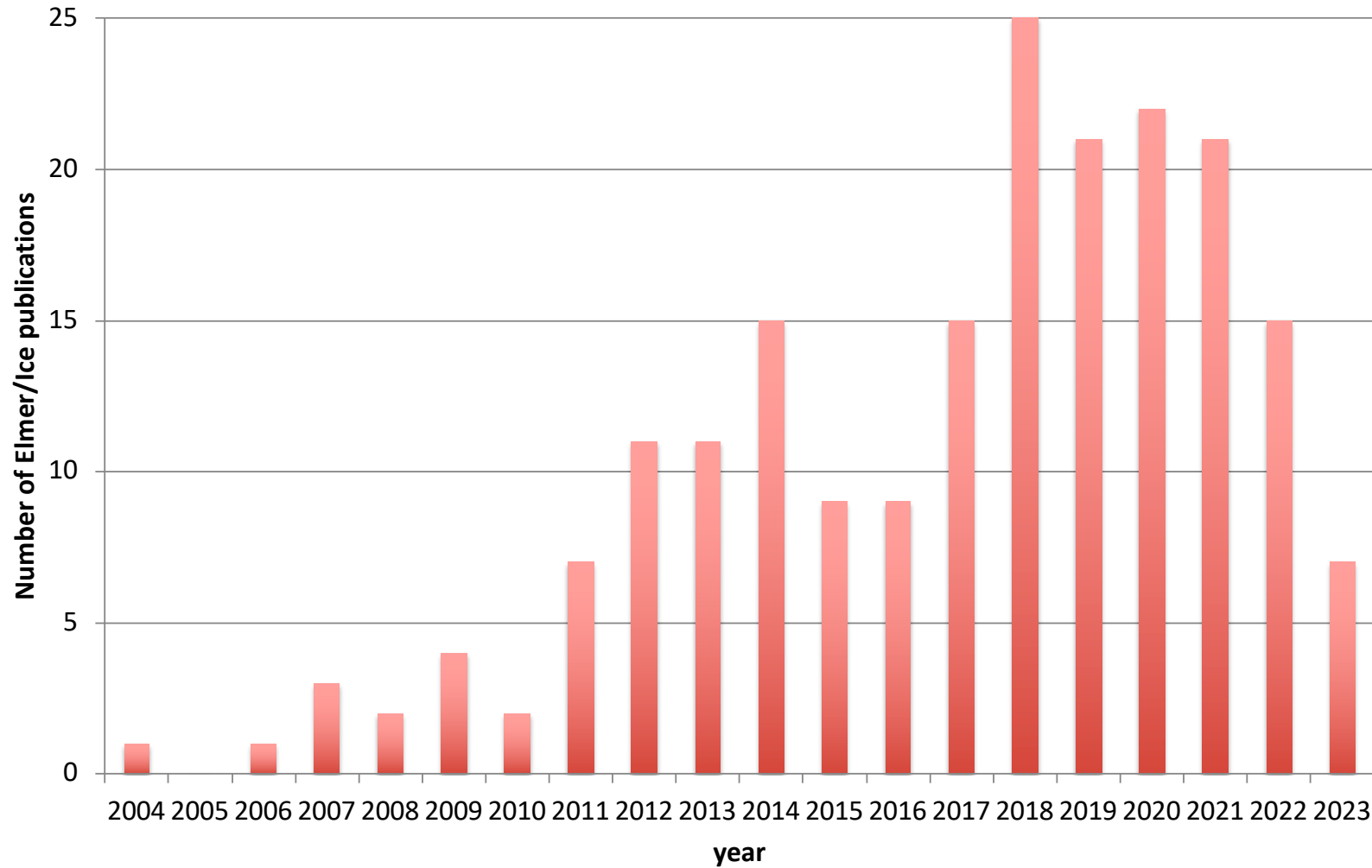
Elmer/Ice – short history & community activity (4/4)

- ✓ 2-day beginner Elmer/Ice course, 24&25 October 2022, Univ. Uppsala, Sweden
- ✓ 9th Elmer/Ice User Meeting - Remotely 7 December 2022
- ✓ 10th Elmer/Ice User Meeting - EGU, Vienna 2023

20 Courses ~ 400 participants → + this one in Finland!

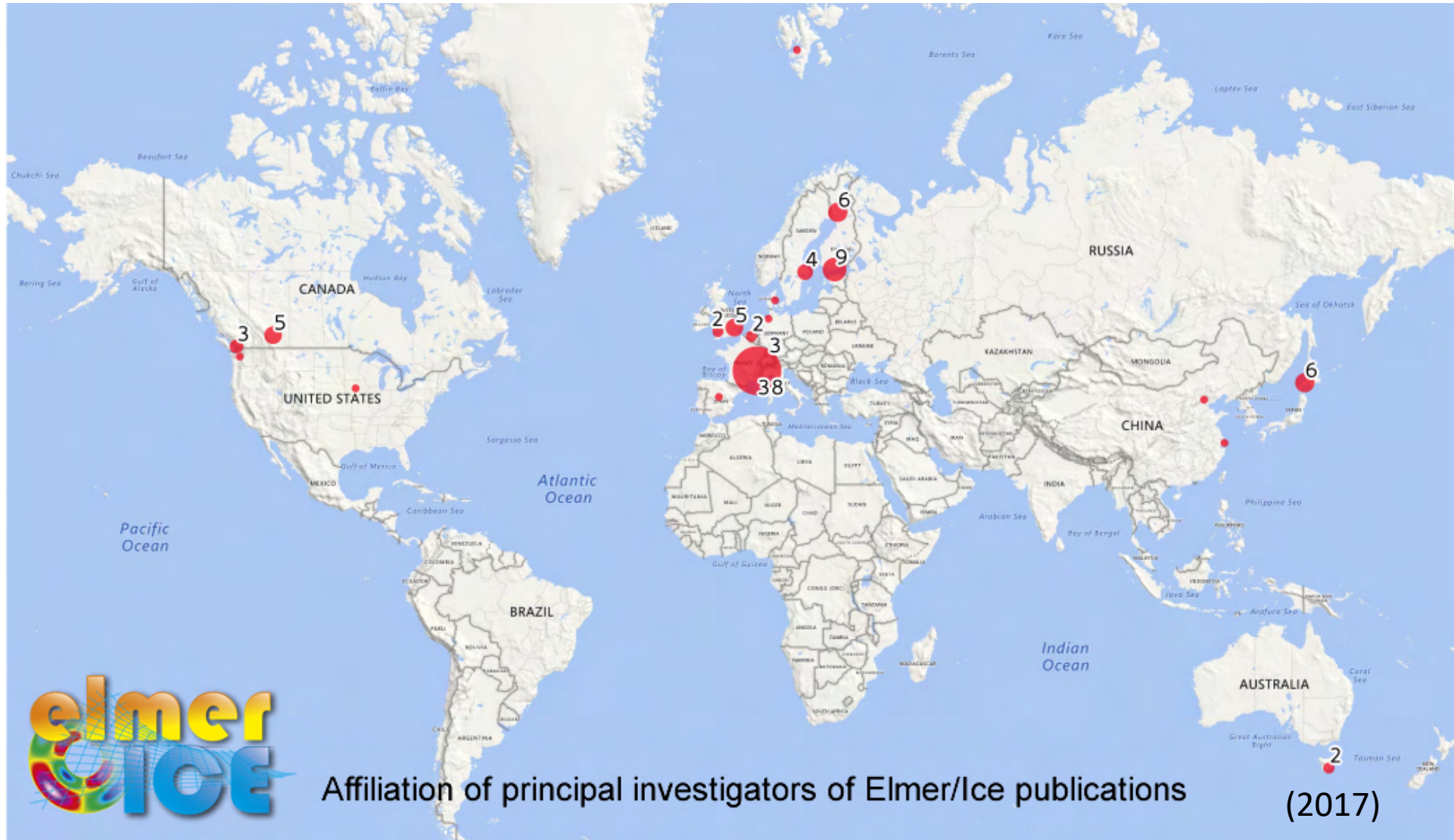
10 Elmer/Ice users meetings → next one this Wednesday

Elmer/Ice - Community



201 publications

Elmer/Ice - Community



Affiliation of principal investigators of Elmer/Ice publications

(2017)



Elmer/Ice website

<http://elmerice.elmerfem.org/>

- **Community web-portal:**

- Latest news
- List of publications
- Forum (see later)
- Courses (indirect link to Wiki)
- Direct link to Wiki

Elmer/Ice News

WRITTEN BY OLIVIER GAGLIARDINI.

The stability of present-day Antarctic grounding lines

Theoretical and numerical work has shown that under certain circumstances grounding lines of marine-type ice sheets can enter phases of irreversible advance and retreat driven by the marine ice sheet instability (MISI). Instances of such irreversible retreat have been found in several simulations of the Antarctic Ice Sheet. However, it has not been assessed whether the Antarctic grounding lines are already undergoing MISI in their *current position*. Here, we conduct a systematic numerical stability analysis using three state-of-the-art ice sheet models: Ua, Elmer/Ice, and the Parallel Ice Sheet Model (PISM). For the first two models, we construct steady-state initial configurations whereby the simulated grounding lines remain at the observed present-day positions through time. The third model, PISM, uses a spin-up procedure and historical forcing such that its transient state is close to the observed one. To assess the stability of these simulated states, we apply short-term perturbations to submarine melting. Our results show that the grounding lines around Antarctica migrate slightly away from their initial position while the perturbation is applied, and they revert once the perturbation is removed. This indicates that present-day retreat of Antarctic grounding lines is not yet irreversible or self-sustained. However, our accompanying paper (Part 2, Reese et al., 2025) shows that if the grounding lines retreated further inland, under present-day climate forcing, it may lead to the eventual irreversible collapse of some marine regions of West Antarctica.

See the [TIPACCS video](#) explaining the results of these two papers!

To read more: Hill E. A., B. Urruty, R. Reese, J. Garbe, O. Gagliardini, G. Durand, F. Gillet-Chaulet, G. H. Gudmundsson, R. Winkelmann, M. Chekki, D. Chandler and P. M. Langebroek, 2023. *The stability of present-day Antarctic grounding lines - Part 1 : No indication of marine ice sheet instability in the current geometry*, The Cryosphere, 17, 3739–3759, doi:10.5194/tc-17-3739-2023

and the companion paper: Reese, R., J. Garbe, E. A. Hill, E. A., B. Urruty, K. A. Naughten, O. Gagliardini, G. Durand, F. Gillet-Chaulet, G. H. Gudmundsson, D. Chandler, P. M. Langebroek and R. Winkelmann, 2025. *The stability of present-day Antarctic grounding lines - Part 2 : Onset of irreversible retreat of Amundsen Sea glaciers under current climate on centennial timescales cannot be excluded*, The Cryosphere, 17, 3761–3785, doi:10.5194/tc-17-3761-2025

Created on 19 September 2023.
Last updated on 19 September 2025.
Hits: 69
WRITTEN BY OLIVIER GAGLIARDINI.

Elmer/Ice wiki

<http://elmerfem.org/elmerice/wiki>

- Contains documentation on Solvers, Userfunctions and also methods
 - We are porting documentation of software to GitHub (see following slides)
- Contains also material of courses

[[start]] ELMER/ICE WIKI

Trace: • courses • firstmeeting • courses • start

Show pagesource Admin Recent Changes Sitemap Log In

Search Search

- Home
- Problems
- Solvers
- User Functions
- Mesh Generation
- Tips and Tricks
- Documentation
- Who is doing What?
- Compilation and Tests
- Links
- Elmer/Ice-sheet

Welcome to the Elmer/Ice wiki

Elmer is an open-source, parallel, Finite Element code, mainly developed by the CSC-IT Center for Science Ltd. in Finland. Elmer/Ice builds on Elmer and includes developments related to glaciological problems. On this page you will find documentation and examples of the various solvers and user functions developed for **glaciological** applications using Elmer/Ice.

Get Elmer/Ice via [GitHub](#).

The [Problems Section](#) presents the various categories of glaciological problems that can be solved using Elmer/Ice.

The [Solvers Section](#) and the [User Functions Section](#) describe the glaciology related solvers and user functions, respectively, that can be used to solve these problems.

Tools that can be used to mesh glacier and ice-sheet geometry are presented in the [Meshing Section](#).

The [Tips and Tricks Section](#) gives some useful demo of MATC, Post-treatments of results and more.

The [Documentation Section](#) contains presentation as well as material proposed in the framework of the Elmer/Ice courses dispensed since 2008.

The [Who is doing What Section](#) gives some information about who is doing what in the Elmer/Ice community.

Useful instructions about how to download and build Elmer/Ice are given in the [Compilation Section](#).

Some useful links are given in the [Links Section](#).

Scientific publications presenting glaciological applications with Elmer/Ice are listed in the [Elmer/Ice website](#).

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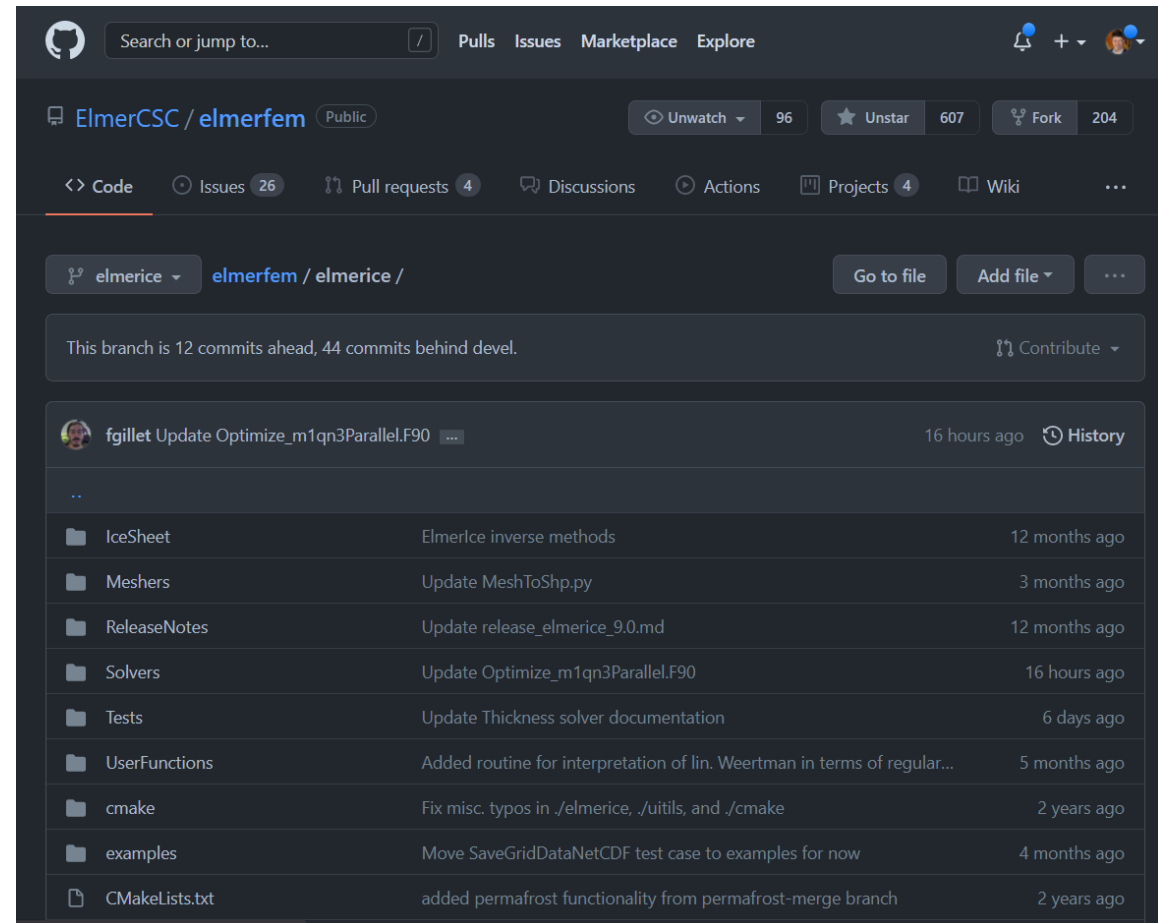
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Elmer source code

<https://github.com/ElmerCSC/elmerfem>

- Elmer/Ice specific files in subdirectory `elmerice`
- Elmer/Ice specific developments in branch **elmerice**
 - We merge frequently between the main branch (**devel**) and **elmerice**-branch
- Porting **documentation to GitHub**
 - `elmerice/Solvers/Documentation`
 - `elmerice/UserFunctions/Documentation`



Elmer/Ice mailing list

Subscribe to the Elmer/Ice mailing list:

http://mail.elmerfem.org/mailman/listinfo/elmerice_elmerfem.org

Not a big flux, but important information (bug, new version, new publication, etc..)

Currently 85 members

Elmer/Ice Forum

Under <http://www.elmerfem.org>

- Go to **Elmer Forum**: find answers on all aspects of Elmer
- Click on **Elmer/Ice** link: find answers specific to Elmer/Ice
- To get access: **Register** in upper right corner

FORUMS	TOPICS	POSTS	LAST POST
General General discussion about Elmer	682	2967	Derivation magnetic co-energy by Itnschlgr Yesterday, 23:51
Installation & compilation Discussion about building and installing Elmer	359	1909	Re: ubuntu packages on launch... by raback 30 Oct 2020, 16:51
ElmerSolver Numerical methods and mathematical models of Elmer	1943	9714	Re: Anisotropic electric cond... by raback Yesterday, 12:54
ElmerGUI The graphical user interface of Elmer	399	1970	Re: FreeCAD .step file doesn'... by Gary R 31 Oct 2020, 02:35
ElmerPost Post processing utility for Elmer	125	528	Re: Some artefacts (nodal for... by mabor 08 Jul 2020, 00:33
Elmer/Ice Extension of Elmer in computational glaciology	96	426	Re: Adding a Thermally Active... by alden Yesterday, 01:12
External tools Mesh generators, CAD programs, and other tools	190	926	Re: Meshing the flow but not ... by Gary R 31 Oct 2020, 20:33
Software development Discussion about coding and new developments	72	309	Re: Setting values to specifi... by hisham.noaman 19 Oct 2020, 17:42
Bug reports Clearly defined bug reports and their fixes	164	519	Re: Simple Hexahedral Mesh No... by gschrack Yesterday, 06:02
Contributed Cases Elmer cases by the users for the users	37	128	Re: Modelling Acoustics with ... by CrocoDuck 19 Jun 2020, 21:40
HPC High Performance Computing with Elmer	11	32	Pointer to -> HPC Europa3 cal... by raback 30 Jan 2020, 21:47
Commerical services A forum for commercial service requests and offerings	9	11	rdw.fi - when ever you are re... by joni 12 Feb 2019, 11:08

Elmer/Ice Slack space

- You should have received an invitation to join
- Can be used to ad-hoc communicate, particularly, in advance and during courses
- Is used by some members afterwards
- Main technical questions: please put them to the Forum, rather than in Slack! Thereby they can be looked up by a wider range of users.

The screenshot shows a Slack interface for the channel '#beginner-course-nov-2021'. The left sidebar lists various channels and direct messages, with '#beginner-course-nov-2021' selected. The main content area shows the channel name, a description: 'You created this channel on October 20th. This is the very beginning of the #beginner-course-nov-2021 channel. Description: Communication channel for the course in Oslo (edit)', and a list of recent messages. The messages include: 'zwingertomas' joining the channel, 'zwingertomas' setting the channel description, 'Samuel Cook' being added to the channel, and 'zwingertomas' pinning a message that says 'Drop your messages (mainly in advance to the course) in this channel - by that we can be sure that all other participants can see answers and we avoid redundancies (edited)'.

Useful Links

- Elmer at CSC (documentation, how to install, ...)

<http://www.elmerfem.org/>

<https://www.csc.fi/web/elmer>

- Elmer (and thereby Elmer/Ice) source code

<https://github.com/ElmerCSC/elmerfem>

- Elmer Forum

<http://elmerfem.org/forum/>

- Elmer/Ice webpage

<http://elmerice.elmerfem.org/>

- Elmer/Ice wiki

<http://elmerfem.org/elmerice/wiki/doku.php?id=start>

About this course

- We will not teach finite element method (can give references)
- We will focus on some technical aspects of using Elmer for glaciological applications
- Expected outcome of this course :
 - giving you a kick-start with Elmer/Ice
 - some possible fruitful collaborations to begin

- **Conduct:**

https://github.com/ElmerCSC/elmerfem/blob/devel/CODE_OF_CONDUCT.md